

ADVANCES IN THE STATE OF THE ART—AND SCIENCE—OF ESPRESSO

BY VINCE FEDELE

To me, a truly fine espresso is one of life's great culinary pleasures. When executed perfectly, this beverage expresses the essence of a great coffee in its purest form, in an intense, balanced myriad of flavors and textures. A morning cappuccino with fresh, perfectly foamed milk, in traditional portions is nearly a meal on its own, and one of my favorite ways to start the morning. I met Sarah Allen of *Barista Magazine* in the summer of 2009 at the

American Barista & Coffee School in Portland, Ore., following a talk I had given about the new coffee and espresso refractometers. Part of the talk focused on the challenges of shot-to-shot consistency and how it related to filters and we discussed how this problem had been discovered. When Sarah heard I was working on a solution, she asked me to write this article. Parts of the project evolved over months, and have now come full circle.

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IDENTIFYING AND SOLVING FUNDAMENTAL ISSUES IN FABRICATION OF FILTERS

During development of the VST Espresso Refractometer in 2008–2009, I began to notice significant differences in how certain portafilter baskets behaved under identical test conditions. Thousands of measurements, accumulated over months of testing a wide variety of filters, confirmed that many could not extract espresso within normal regions on the brewing control chart. Meanwhile, other filters that previously tested good continued to extract normally with respect to taste as well as where they measured on the chart and behaved predictably. Testing of the water and key metrics of the espresso and grinding equipment confirmed all within normal tolerances. There was no single, simple answer.

Consequently, I organized an approach integrating individuals from different disciplines within VST (i.) in a combined effort to help identify and develop solutions to address four fundamental problems:

- develop a new measurement system to ensure specifications integrity;
- develop a new hole forming methodology to ensure precision and uniformity;
- solve materials problems with premature failures;
- understand and develop a process to solve problems with extraction and flow control to harmonize filter design.

Much of the craft of espresso, like many things Italian, has evolved over decades with little of the science behind the craft well understood or published, let alone available to those outside of the industry. Even within the espresso machine industry, manufacturers have struggled with difficulties maintaining tight tolerances in the manufacture of portafilter inserts, namely espresso filter baskets, manufactured by

a limited number of suppliers, using dated techniques. To the best of my knowledge, none of the espresso machine producers actually manufacture their own filters.

Espresso machine manufacturers, specialty coffee roasters, professional baristas, café owners, and coffee enthusiasts have struggled to understand the science behind espresso extraction in order to improve espresso beverage quality as well as their barista skills. With a nod to the differences between the beverages, espresso and coffee, there are many common factors, as well.

MEASUREMENTS AND A PLACE FOR SCIENCE

The basic chemistry of espresso is similar to that of coffee, extraction-wise, albeit at a much higher concentration (please accept the simplification for this part of the discussion; obviously, espresso has a great deal of other nuances that characterize its unique attributes, blending and single origins, roast profile, crema, and lipids).

The total brew solids include both dissolved and non-dissolved solids in espresso. Strength, in percent TDS (total dissolved solids, or concentration) is determined by filtering the non-dissolved solids, then measuring concentration by refractometry or by dehydration oven. When the dose and beverage weights are known, extraction yield can be computed and charted. In a proper extraction at a given strength, extraction yield is by far the most important attribute to track regarding taste defects. (Figure 1). Similar to taste defects which have been used to describe over- or under-extracted coffee for some 60 years, similar attributes apply to espresso, but are much more pronounced at the [10x] higher concentration.

The non-dissolved solids are ~70% cellulose by weight, and are not soluble in water, so they must be excluded from the TDS measurement since they do not participate in the extraction. In a properly fabricated filter, VST has measured non-dissolved solids typically in the range of 4–6% of the total brew solids. In some poorly fabricated filters, the non-dissolved solids measured 9–13%, producing a vegetal, chalky beverage.

Within that sediment are excessive amounts of the diterpenes cafestol and kahweol, known to increase production of serum cholesterol levels (ii.), and so it's desirable, therefore, to minimize these non-dissolved solids. A properly designed and fabricated filter reduces non-dissolved content by approximately half. These measurements can easily be repeated by dehydrating filtered and non-filtered samples of the same beverage, and computing the percent of total brew solids attributable to the non-dissolved component.

PRACTICAL TDS MEASUREMENTS

Ole Sønstebø of the Norwegian Coffee Association at the European Coffee Brewing Center in Oslo recently conducted tests over the months of July through November in 2010, carefully comparing oven dehydration techniques they have used for the past many decades to recent advances using refractometry, and concluded refractometry was faster, and equally accurate, with much less of a chance of error. The Specialty Coffee Association of America (SCAA), the Specialty Coffee Association of Europe (SCAE) and Coffee Analysts (Coffee Enterprises' Laboratory facilities in Burlington, Vt.) have conducted similar tests. All found the coffee refractometer to be accurate for these purposes. Dehydration frequently takes a period of eight to twelve hours, uses a great deal of energy and requires expensive, accurate scales and flawless laboratory protocol. Microwave dehydration takes less time, but typical systems cost at least \$18,500 USD. Coffee refractometers cost \$399–\$599 (iii.).

CHARTING YOUR MEASUREMENTS

Data is of little value if you don't have a way to visualize and use the information. The brewing control chart is an outstanding tool to understand the basic high school chemistry behind a simple solution.

Espresso extraction can be looked at as a method to accelerate the brewing process, using the catalyst of pressure combined with a much finer grade of grind. With the advent of the coffee refractometer, and extended capabilities of the brewing control chart, it's now an easy matter for anyone to accurately measure extraction yield and concentration to better understand exactly what has been brewed, and associate those measurements with your primary taste preferences as you perceive them. In this manner, it becomes a simple exercise to repeat those extractions you prefer, wherever they might fall on the chart.

Measurements are also extremely helpful in trouble-shooting extraction problems or inconsistencies.

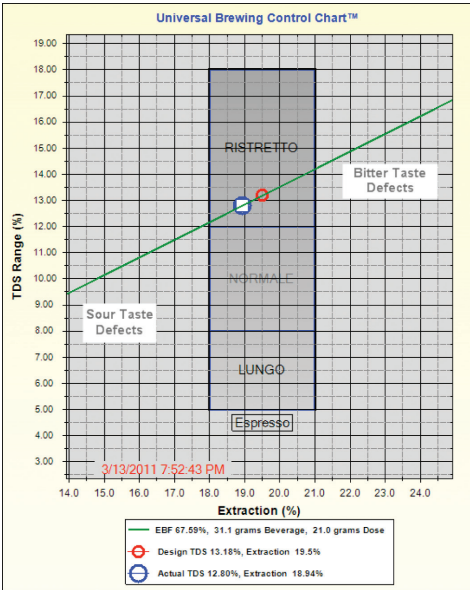


Fig. 1

These problems turn out to be equipment related more often than one might expect, usually attributable to one or more faulty filter baskets. Assuming a barista with base level or better skills can repeat an espresso brewing protocol with consistency (dose weight, distribution, tamp, and beverage weight), measurements can be made readily by anyone using a coffee refractometer and brewing control chart.

Most modern espresso machines are very good at providing uniformity with respect to temperature, pressure and flow rates. The ability to chart (extraction yield and concentration) measurements makes it a simple exercise to gather data. Evaluating the data—starting first with how the shots taste, and then noting where they fall on the chart, as well as why they fall where they do—can dramatically improve espresso quality as well as shot-to-shot consistency.

A word about method of shot terminations: much has been discussed recently about using beverage weight versus more traditional volume as one of several indicators as to when to terminate the shot. Beverage amount is only one of many attributes that determine when to terminate that include the range of shot time, color and texture, delay before the pour starts and

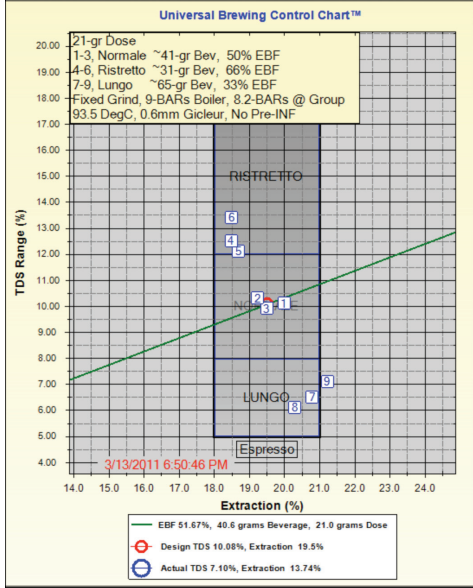


Fig. 2

others. Assuming these factors are within what a barista knows to be normal ranges, termination by weight is a far better method to obtain consistent TDS and final extraction yield than is volume. Volume is essentially meaningless, given that a fresh coffee, i.e. one not allowed enough time to outgas, will generate massive amounts of crema and volume (and less mass) than a coffee that has had adequate time to outgas (10+ days for some high-density coffees). Roasters in the know often specify even longer times.

Virtually all cafes run into practical order and delivery flow problems, and cannot always use espresso that has been rested seven to ten days before use.

Since most extraction occurs early in the shot, extending time provides mostly dilution (i.e. lower concentration), but in a properly performing filter, not much more extraction yield. Finally, I sometimes see roasters specifying shot parameters, and agree it's a good idea to do so. Frequently though, the specifications use mixed units of grams weight for dose, and fluid ounces for beverage amount, which is a unit of volume. Often, volume is referred to as an ounce, which is actually a unit of weight.

Units of **Weight** are grams (gr) and ounces (oz).

Units of **Volume** are milliliters (ml) and fluid ounces (fl-oz).

For purposes of espresso (and single-serve coffee), it's easier, less confusing and usually more accurate to use consistent units of weight (grams dose/grams beverage/grams brew water) when specifying brew formulas.

DIAL-IN YOUR SHOT

The efforts required to dial-in an espresso beverage are challenging to impossible if filters are incorrectly designed and fabricated, moreover, if they're different in each group. When a filter is properly designed and fabricated, and used at or near its design capacity, consistent shot-to-shot results are readily achieved, and very forgiving. Anyone with modest skills can repeat with precision using a decent filter (see Fig. 2). I know this because I'm one of them.

Given that most professional-grade hardware these days is generally capable of providing extraordinarily consistent temperature, pressure and flow, there are three other crucial factors that significantly affect extraction flow rates (i.e., contact time and extraction yields): *particle size*, *coffee depth* and *total cumulative open area* in the filter. There is a relationship between these three attributes that must be harmonized for each filter capacity. A filter with correct hole size and total open area designed for 21–22 grams will not and should not be expected to extract normally when filled to only 14–15 grams. It will pour too fast, causing you to try to throttle flow by grinding finer. The problem is that the holes and total open area are sized for a bed depth of 21-gr, so grinding the coffee finer without also reducing the hole sizes will in effect de-tune the filter. The non-dissolved brew solids component will spike, and you'll over-extract the coffee, providing both a bitter and chalky final beverage.

Similarly, if a filter has a large quantity of holes that are too large for its design capacity, then the barista is forced to grind finer to throttle flow, even when filled to normal capacity. This will inevitably produce a similarly over-extracted, sediment-loaded and unacceptable beverage. If a filter has a substantial deficit (too little open area), the barista is forced to grind too coarse, causing faster pours and reduced particle surface area to extract from, and results will taste sour and will measure under-extracted (Fig. 7, 6-10).

Comparing the 21-gr filter used with 14-gr dose as discussed above, to a properly designed and fabricated 14-gr filter, the 14-gr holes will be slightly smaller, as will be the total cumulative square open area. Consequently, as the grind is made slightly finer, to accommodate the shallower bed depth, the flow, contact time and extraction yield will behave predictably, and plot to the same areas of the brewing control chart as any other properly tuned filter at another gram capacity.

There will not be a rise in sediment, because the peak of the particle size (Fig. 3, red) distribution moved down, to track the peak of the hole size distribution (Fig. 3, blue). This

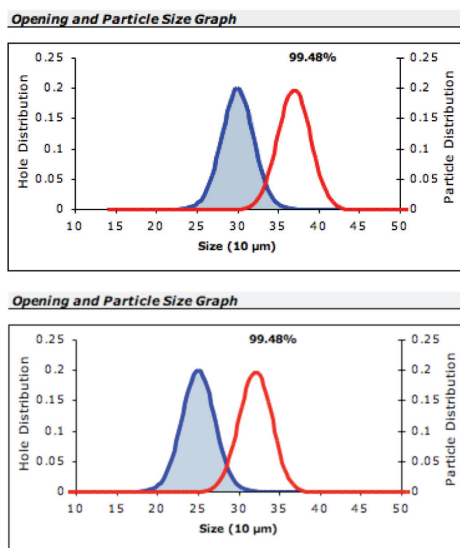


Fig. 3

is what is meant by harmonizing the filter performance for correct extraction, and is an important missing link in filter design that has plagued the industry for a number of decades. It is desirable to keep the overlap to a minimum, to keep sediment levels to less than 4–5%. This also means maintaining sharp burrs and keeping grinders clean on a daily basis. Finding a good filter was, in general, the exception. In addition, manufacturing techniques are crude, producing poor precision (repeatability) and widely variable hole size distribution, which can be seen in a histogram, a valuable tool VST developed and applied to filter measurements for evaluating quality.

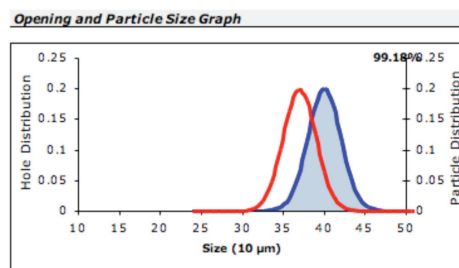


Fig. 4

Example of holes (blue) too large, where the coffee (red) is ground so fine that it is smaller than the holes. This results in extremely erratic flow with minute grinder adjustments, humidity changes, or no apparent changes at all. Sediment levels can exceed 9% of TBS.

SOLVING THE PROBLEM(S)—A NEW MEASUREMENT TECHNOLOGY

All other things being equal, significant differences in filter basket total cumulative open area, and relative size and distribution of holes are among the primary reasons shot-to-shot consistencies are frequently so erratic.

During development of the espresso refractometer, in 2008 and 2009 I observed significant inconsistencies among members of small groups of filters as supplied with new espresso machines or as purchased from any number of manufacturers or after-market resellers. Plotting the data on a brewing control chart helped identify sharply different performance regarding extraction yields and concentration. Cumulative total open areas varied more than 3:1 in a small lots of 30–50 filters (same part and LOT number), ranging from 30 to 120 sq mm, for example.

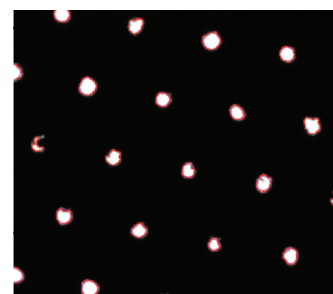


Fig. 5

I sent two filters to a metrology lab. The filters were returned marked NOT MEASUREABLE, with a photo (Fig. 5) of a cross section showing why: irregularly shaped holes that varied in size by what appeared to be more than 3:1. Edges of the holes were torn, rather than cleanly cut, punched or drilled, with ultra-thin, foil like edges, and were not de-burred. When not properly de-burred, these edges can deteriorate, and erode in practice. In a properly fabricated filter, even one with irregular shaped holes, these are all removed with a polishing process. Clearly, many filters, including some after-market varieties, had not been

polished to the required standard. This is why food-grade certifications are required, and part of all espresso machine testing. Most filters from OEM manufacturers we looked at were properly polished and de-burred. Even after proper polishing, however, many holes were completely blocked, acircular or partially occluded. Without circularity (and a clear idea of diameter), $\text{area} = \pi \cdot r^2$ won't work. Holes must be circular to use diameter and realize accuracy in determining cumulative total open area.

Without a method for measurements available VST began development of a new measurement system in 2009 to address the problem. Area, not diameter, must be measured because the holes are rarely circular. Furthermore, the total square area is cumulative. The design target was to achieve an area accuracy of better than +/- 1%, or about 0.5 sq mm in 50 sq mm, with a precision of +/- 0.1 sq mm.

Poorly fabricated filters, with many blocked and partially occluded holes had demonstrably slower flow, when using the same grind setting as a normal filter. This required a significant step towards a more coarse grind, in order to obtain normal flow, and shot times (Fig. 7, 6-10). However, the shots tasted sour, and all measured significantly under-extracted, as compared to the normal filter.

Key to being able to evaluate quality was developing a method of fast, accurate measurement, as well as how to characterize and use the data. A combination of total cumulative area, statistical distribution of the hole sizes (histogram), and how to manage the calculations for tuning these attributes to depth and particle size was required, as discussed below. The measurement system had to be capable of processing a measurement in less than 200mS, to allow measurement of hundreds of filters per minute. With this capability, the new VST Filter Imaging System could guarantee zero filter defects, because it would be a practical matter to measure 100% of all filters produced, quickly and inexpensively, ensuring exceptionally high quality control.

An example of the difference between filters is readily apparent when data are presented in this form.

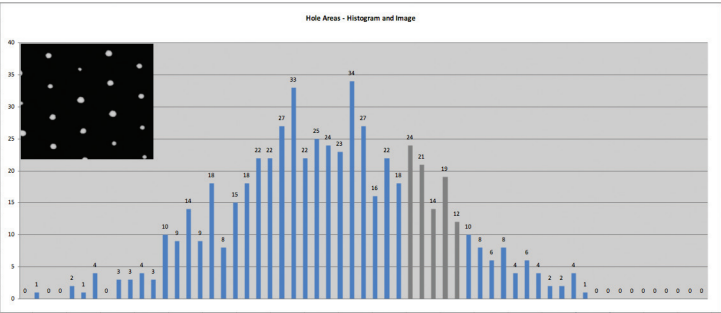
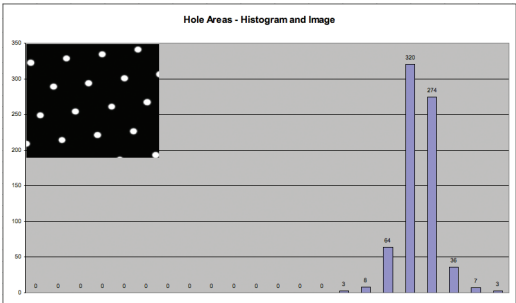


Fig. 6a



Poor control of Fig. 6b

hole sizes, including hundreds of blocked or partially occluded holes. Total square opening area is considerably restricted. Holes fall over some 40 size class intervals (Fig. 6a). Frequency is shown for each size.

A properly fabricated filter, with hole counts showing a normal distribution in only five class intervals (Fig. 6b). These five class intervals are highlighted in gray in the histogram, above, for the poorly fabricated filter.

The correctly fabricated filter has a normal, Gaussian distribution, over only five size class intervals. The faulty filter, shown on a similar scale, has more than forty. The difference in how the filters performed in use was significant. The filter that extracted normally (Fig. 7, 1-5) also brewed predictably, produced excellent tasting, well balanced espresso. Total open sq area was in the range of 60 sq mm.

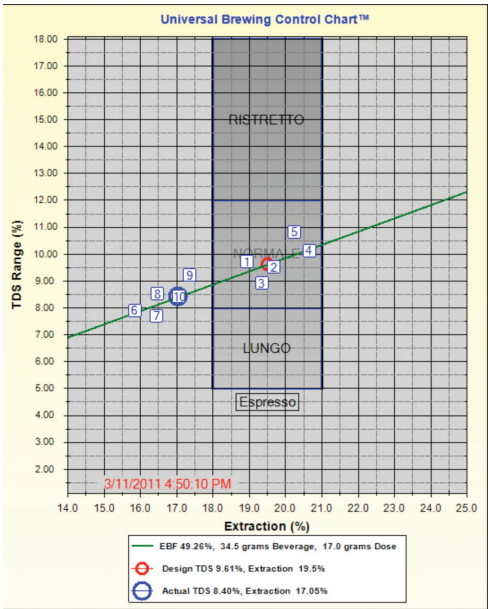


Fig. 7

Measurements plotted in the range of 19–21% Extraction Yield. Ristretto and lungo pulls were readily delivered.

It was not possible to dial-in the faulty filter beyond about 17% yield. The grind was too coarse, and the shots poured too fast. Grind setting was sensitive to small changes, the espresso tasted sour and under-extracted, and crema and color were compromised. Total open area measured just 26.5 sq mm, less than half the open area of the normally performing filter designed for the same dose capacity.

This proved to remind me that coffee particle surface area is a square function, accordingly, even a small change in the direction of a coarser grade of grind reduces considerably the surface area available to extract from while at the same time increases flow rate. The analogy is water flowing through sand versus through stone. Consequently total contact time is reduced, causing significantly under-extracted, sour tasting shots.

THE FAULTY SHOTS WILL FOLLOW THE FAULTY FILTER

The corollary was immediately apparent, and both taste and measurements were readily confirmed. When the same two filters are placed into any other espresso machine, with similar flow restrictions (i.e., plumbing and gicleur), pressure and temperature, the shots measured will plot in a cluster and in the same regions on the brewing control chart, with taste once again confirming final shot quality.

Making these simple measurements can be done by anyone with a scale and coffee refractometer, consequently allowing you to separate existing filters by seeing where they perform. Simply pull 5-6 shots with each filter, measure and plot where they fall on the brewing control chart. When you have satisfied both conditions, i.e., that they match each other and they fall in the region you prefer, you have matched performance in

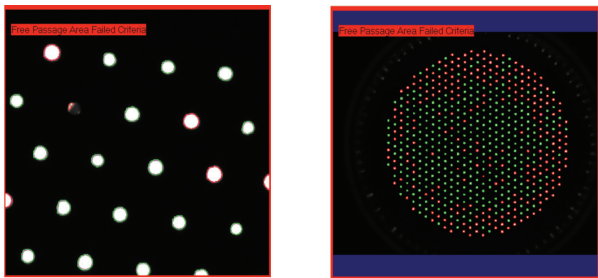
each group. Mark the preferred filters, and discard the others.

EXAMPLES OF HOLES IN CURRENTLY AVAILABLE FILTERS:

Typical of most filters using traditional fabrication methods. Poor quality,

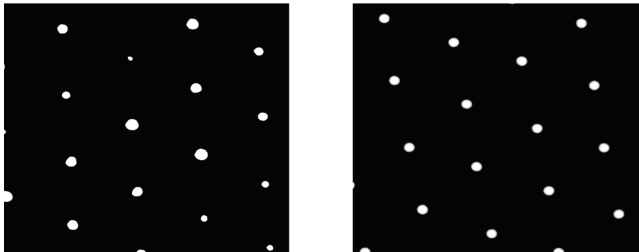


inconsistent open area, wide variances in sizes and circularity. Holes are circular, but with wide variances on size, and many partially



blocked holes. Red highlights indicate sizes that are out of specification.

Left: Holes are circular, but with very wide variances on size, but no



blocked holes.

Right: Properly fabricated filter. Holes are uniform, circular, and meet specifications for size.

Fig. 8

Test criteria include hole count, area, diameter, circularity, range limits, hard limits, total open area, and about a dozen other criteria. Each attribute can be set to monitor specifications, alone or in combination to determine final pass/fail status.

HOLE FABRICATION PROBLEM

With a new measurement system in place to ensure filter design specifications were being met, and could be measured and processed at a rate of hundreds per minute, the next set of challenges were to identify or design a new method of fabrication that would solve the hole quality

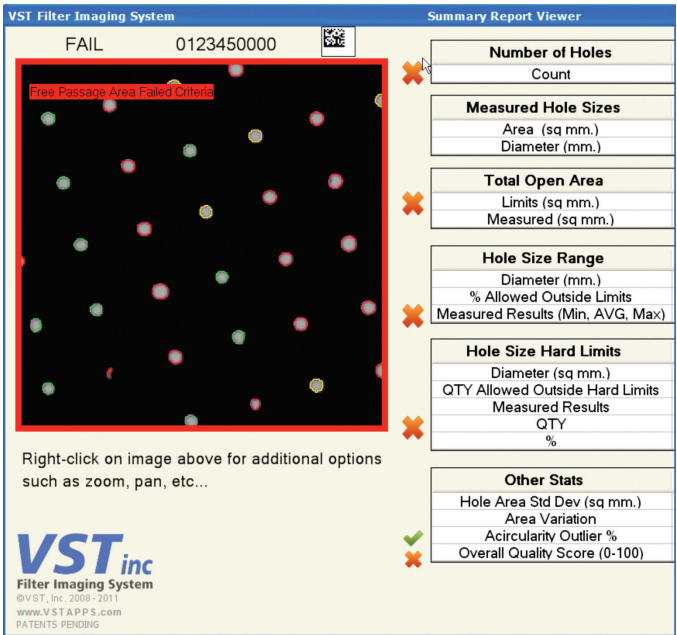


Fig. 9

Sample Screen Shot of VST Filter Imaging System Quick View

problems.

The method had to provide any specified size of hole with guaranteed circularity, uniformity of area, and geometry to a precision not yet achieved in modern filter designs. Maintenance of the cross sectional shape was also critical in the final method to avoid clogging. In the process of assessing available technologies, a few were identified that indeed provided better circularity and well controlled hole sizes. The problem, however, was these filters did not stand up to commercial use, and tended to fail prematurely due to fatigue stress cycling (Fig. 11). Originally intended for consumer-grade espresso machines, they can perform well but only for a limited number of cycles. Moreover, available filter shapes were not conducive to uniform extraction throughout the puck, and total open areas were not harmonized to extract properly throughout typical TDS ranges (Ristretto, Normale, Lungo).

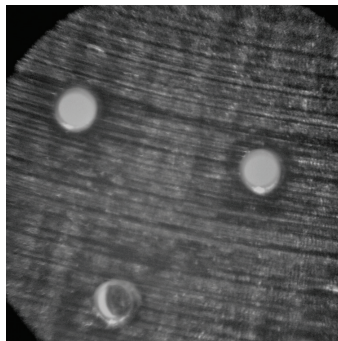
Some available after-market filters showed promise, and positive attributes, but could easily be broken after just 12–16,000 cycles (one to two days on a cycler). In a busy café using 18–21 gram doses and 100 pounds of coffee per week, in a two or three group machine, that could be as little as 45–65 days use. To confirm, we sent a set of three to Myriad café in Montreal, where Anthony Benda and Scott Rao hammered on them in their busy shop near Concordia University. Two of three broke within 55 days. The failures occurred at the edge or in a stair-step pattern along the holes. In order to stand up to commercial use, a filter must withstand at least 120,000 cycles without any degradation or change in extraction performance.

Most filters start out as a sheet of stainless steel (various high quality grades are used), out of which is punched a circle. A two-part stamping die consisting of 300–800 pins with conical, 4- or 6-sided points (positive) is mated to a receiver (negative) on the opposite side. A multi-ton press forms the start of the holes, but they are not punched all the way through. A common process uses a cutting tool to mill off the indentations while being careful to maintain the original thickness of the material, thereby creating the opening. If the cutting tool is not

sharp, or is moving too fast, the opening created is jagged, rough and metal is stretched and sometimes torn. Stainless steel is very difficult to work in this manner. Drilling or stamping is a better process, because stainless tends to gall. The next stage forms the cup, and then the ridge and rim. The final process is a de-burring operation that is generally a tumbling process using water and abrasives (ceramic beads). Better filters are made using longer and more costly final polishing processes, finish can be matt or polished. All should be food grade certified. This process is the most common used for today's commercial filters. Some filter manufacturers offer laser processes to form holes or to clean up burrs, but this process, readily identified, often vaporizes metal in unintended areas, and is not necessarily a process that produces the best or even improved [hole] precision.

Better precision comes from processes that micro-machine a few millionths of a meter below the top inside surface, actually removing some of the material, and micro punches the final hole. Other, more modern laser methods can, when combined with certain micro-machining processes, produce superior hole precision while maintaining hole

Fig. 10



Final hole forming process showing de-burred inside edge, and punched hole just prior to clearing with compressed air.

geometry. However, this method can cause other serious problems if too much material is removed. Loss of circularity of the holes, and premature fatigue failures are common because the structural integrity of the filter is compromised. Intended for non-commercial use, these filters may work fine on consumer-grade machines with limited use.

The fatigue mechanism is simple repetitive flexing. When the pump reaches nine BARs, and flow is initially restricted during a shot,

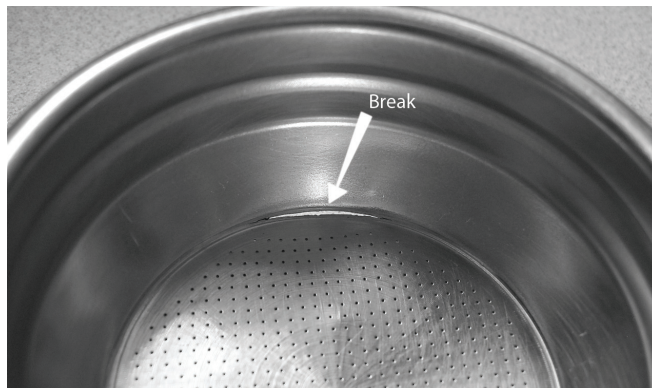


Fig. 11 *Fatigue stress failure typical of currently available after-market filters, after less than two months on bar at Myriad Café in Montreal.*

the bottom of the filter is pushed out from the considerable force of the pressure. Nine (9) BARs ~130 psi (pounds per square inch). A typical

59mm filter experiences 550 pounds (250 Kgs) of force when the pump is at full pressure. This causes the bottom of the filter to bend down, with the fulcrum at the corner. When the pump is turned off, it returns to its home position. If the material has been thinned too much in the hole forming process, the case with many of the filters we looked at, the filter will fail prematurely in commercial use.

VST addressed these problems with a new process that solves the structural integrity problem while maintaining hole geometry, leaves no burrs, and creates perfectly uniform holes that can be maintained to better than 20µm. Final polishing is fast and provides a superior finish. Filters have been tested to in excess of 140,000 cycles without a single failure.

FINAL FILTER CHARACTERIZATION

Using a combination of the new optical measurement system, the coffee refractometer with brewing control chart and new fabrication methods, VST developed a process for tuning a filter's performance to particle size and coffee height at the traditional pressures of 8–9 BARs and 93.5 Deg C at the group. Each filter is designed for a narrow range of capacity, for example 20-24, 17-19 or 14-16 grams and to extract at the traditional settings of:

~10% (TDS) for A Normale, at 19–20% Extraction Yield, 50% Espresso Brew Formula

~6.5% (TDS) for a Lungo, at 20–21% Extraction Yield, 33% Espresso Brew Formula

~13% (TDS) for a Ristretto, at 18–19% Extraction Yield, 66% Espresso Brew Formula

Finally, an attempt was made to narrow the range of coffee particle [grind] size required for each filter, so that adjustments between filter sizes could be minimized.

A note about filter gram capacity: each filter is designed to perform within these narrow ranges of capacity, because they are a fixed and specific volume in cubic centimeters. Coffee densities vary, but generally are within 0.50–0.55gr/cc. The actual final weight should vary by the density of the coffee, not by over- or under-dosing the filter. For example,

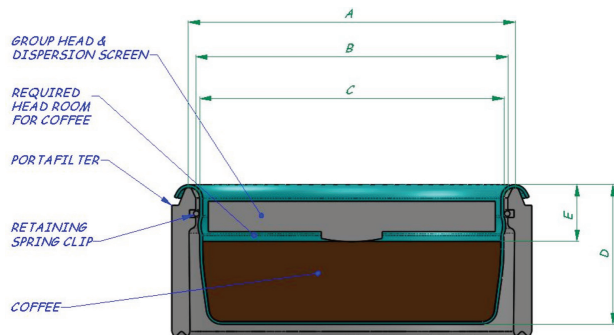


Fig. 12

a high-elevation grown single origin coffee might weigh 24-gr when filled to capacity, while a softer or blended coffee weighs only 22 when filled to the same height. Fill height is designed to be 2-mm below the group screen when evenly dispersed, settled and tamped (Fig. 12).

Generally speaking, you will reach this height when dosed loosely to fill the filter to its rim, settling, then wiping excess off and finally tamping.

The final tamped height will fall just below the bottom edge of the ridge line.

Figure 13 shows espresso shots plotted from each of three different capacity filters tuned using this method, one at each brew formula. For each filter the grade of grind was set for normale, and left unchanged for shots pulled as ristretto and lungo.

Grind settings were slightly more coarse for the 22-g filter and slightly more fine for the 15-g filter, with the 18-g filter mid-way in between. For test purposes, both mill and conical burr grinders were used. Specifically, a Mazzer Super Jolly, Anfim, Robur, and a Compak K-10.

For reference, we used the Compak K-10, and noted the dial collar settings:

See Fig. 13

Nominal Capacity	K-10 Setting	Ristretto Plot	Normale Plot	Lungo Plot
15-g	15	1	2	3
18-g	17	4	5	6
22-g	19	7	8	9

Even with a 5.5-inch diameter adjustment dial, the adjustment range was only about one-half inch, making adjustments fast and easy. Given the same coffee and roast profile, the espresso pours perfectly when the grinder setting is returned to its position as marked for a given filter. The espresso brewed from any of these filters is virtually indistinguishable from another at the same brew formula. While these are nominal design points, desired TDS can be moved readily within a tight cluster of these values. Each filter, regardless of capacity, will perform similarly to another.

SUMMARY

The goal was to develop a system to ensure that each filter design, regardless of capacity, be able to extract a normale, ristretto and lungo within a relatively narrow extraction yield range, identically to each other, except with beverage amounts proportional to dose.

The measurement system can now be a part of the

manufacturing process and used at incoming inspection. Every filter can be measured for compliance to specifications, and tied to a unique ID marked on each filter, and shipped with a report detailing measurements directly from the VST Filter Imaging System.

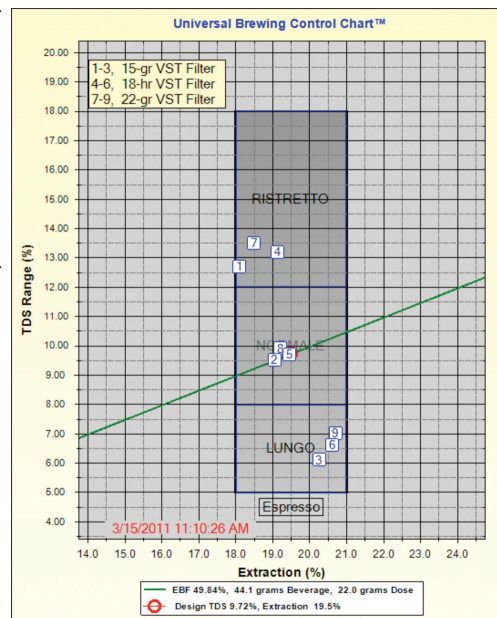


Fig. 13

Any degradation in tooling is detected before the tools need to be replaced, because the histogram signature and related limit criteria are very sensitive to minute changes in tooling dimensions picked up in the measurements. In effect, this guarantees zero-defect filters, and that a given filter design will perform identically when a replacement is purchased for another group, machine or client location at any time in the future. Precision tooling ensures holes meet diameter, circularity and uniformity specifications and imaging certifies consistent cumulative open area and flow at the intended grind particle size – for every filter.

Other design changes were incorporated to eliminate premature fatigue failures. Superior materials provide for structural integrity to greater than 120,000 cycles. Ridge and cup dimensions were tightened to ensure the filter is pulled to the portafilter rim, and held firmly in place. A combination of tapers and radii were carefully designed to facilitate release of the puck when knocked out. Finally, filter cup shape was adjusted and hole patterns expanded to provide for a uniform open exit area under the entire puck.

During early testing, we found that virtually all filters designed with a tapered shape and/or with large radius corners (or both) created a dead zone in the extraction of the puck. In order for coffee to extract uniformly throughout the puck, there must be a uniform open area under the entire coffee bed. Taper and/or large radii corner designs allow holes under only the center two-thirds portion of the puck with effectively no escape vent for a donut-shaped ring around the larger circumference. In practice, this over-extracts the center portion of the puck while leaving the band around the edge (~one-third of the total area) under-extracted and more subject to channeling. Careful testing also confirmed that the transition region between these two boundaries varied greatly with shot time, amplifying the erratic shot-to-shot extraction behavior we measured. This effect goes away completely when a uniform hole pattern is provided under the entire area of the espresso coffee bed. **b**

(i) VST, inc. is a technology and product development company, founded in 1988 by Vince Fedele. VST specializes in embedded processor design, optical and electrical engineering, industrial design, mechanical and chemical engineering and application of advanced materials. See <http://vstapps.com/about/>

(ii.) References:

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The hypercholesterolaemic factor in boiled coffee is retained by a paper filter.

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Coffee Consumption and Serum Lipids: A Meta-Analysis of Randomized Controlled Clinical Trials

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(iii) <http://bit.ly/oXpX6x>

FILTER AVAILABILITY

VST will introduce several new models of filters in April at this year's SCAA Expo, and via its web site, <http://store.VSTAPPS.com>

La Marzocco will launch four new filters employing the VST Filter Imaging technologies for the Strada, their new flagship espresso machine. La Marzocco, known as a leader in innovations and technology for the specialty coffee industry, will be the first to do so at this year's Specialty Coffee Association of America (SCAA) Exposition in Houston, April 29–May 1.

Designed by Vince Fedele and Gary Kappel of VST, these filters are fully compatible with all La Marzocco espresso machines, and will be available through La Marzocco's distribution channels in 21, 17, 14, and 7 gram capacities. Visit the La Marzocco booth, #747, at the SCAA Expo to see and test some of the new Strada filters which will be demonstrated during the event.